AN OUTLINE OF BEET SUGAR MANUFACTURE.

By Wm. H. Dobson.

In addition to the sugar cane plant, there are numerous other sources of supply of sugar, some of which are still employed. There is the Sorghum cane (or sugar grass) and maize (or Indian corn). Both of these belong to the same family as the sugar cane, but are much less in sugar content.

The sugar maple is very well known, being mostly grown in Eastern Canada and north-eastern United States, but was probably first used for the purpose in India, but you will never know how nice it is unless you go to these places, as the whole of the good sugar is used at home—not exported. Its main use, of course, is for its valuable hard wood. Annual crop is approximately 20,000 tons.

Then there are the sugar palms, such as the wild Date Palm, extensively cultivated in India.

The coconut palm, the sugar palm of Ceylon, also known as the "Jaggery Palm," is grown in Madras.

The Palmyra palm, or "Toddy" palm, is cultivated in Madras and Burma. This tree lives from 200 to 300 years, and is also valuable for its fruit and wood. The manufacture of sugar from this palm dates back to antiquity. Crop from these three is about 750,000 tons, but reliable figures are difficult to obtain.

The Aren palm is cultivated in Dutch East Indies. There is also the Nipa palm, from which sugar is still extracted.

In 1747 a German chemist—Marggraf—discovered that the Silesian beet contained from 5 per cent. to 7 per cent sugar, similar to that extracted from the sugar cane, and he succeeded in extracting and crystallising small quantities of beet sugar in his laboratory. His discovery remained unused for many years, but his pupil, Achard, subsequently cultivated the roots on his estate in Germany, and built the first beet sugar factory in 1799. The factory produced six tons of sugar per annum at a cost of 2/4 per lb., or £13 per cwt.

Achard's success led King Frederick William of Prussia to provide funds for building numerous beet sugar factories in 1801. Shortly after this France was cut off from her colonial cane sugar supply by the British blockade, and Napoleon, recognising the possibilities of the new industry, ordered 70,000 acres of French soil to be planted with beet in 1811, and founded schools of instruction in the art of sugar making.

History often repeats itself, and during the European war Great Britain herself suffered the same shortage of cane sugar
(and of course also its usual supply of beet sugar from Germany), this leading to the construction after the war of a chain of large factories for beet sugar production in Great Britain.

The white sugar beet, red garden beet and the mangel belong to the same family, and have descended from the wild beet which was used as a vegetable by the Greeks and Romans in ancient times.

The sugar beet is white, and is of similar shape to a parsnip, only larger. Unlike the forage beet (which grows half in and half out of the ground), the sugar beet is almost entirely in the ground.

It is not uncommon to see an odd mangel in the beet deliveries to factories. This does no harm except that its sugar content is of course low.

During the last 100 years enormous strides have been made in breeding new varieties of sugar beet, the sugar content of which is now very high. There are several firms in Germany, Holland and America who specialise in growing commercial beet seed, and most seed used comes from these sources. The choice of seed is a very important matter indeed, and much loss will result if care is not taken to procure seed suitable for the particular climate. Rainfall, soil and temperature must be taken into account.

The soil should not be too light, and must be deeply cultivated in order to ensure the normal development of the tapering roots. In Europe the seed is sown in April, and the harvest gathered in September. One kilogram (2.2 lbs.) of seed should produce 70,000 plants, which are spaced 10 inches apart in each row. To obtain the best results a great deal of labour is necessary during the growing of the crop, and as a general rule the factory authorities superintend at regular intervals the growing of the beet.

The tonnage of “clean roots” per acre varies in different countries, according to the variety of beet cultivated, and varies in different years according to the rainfall. The following figures are averages for 10 years of topped beets:

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<tr>
<th>Country</th>
<th>Tonnage per Acre</th>
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<td>Czecho Slovakia</td>
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<td>Belgium</td>
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<td>Germany</td>
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<td>Holland</td>
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<td>Russia</td>
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But I understand that much higher figures are now obtained in Soviet Russia, due to better seed, supervision, etc.
As far as I know there is only one beet sugar factory in Australasia, that at Maffra, Victoria. It has its own experimental farm, where even seed is being produced with results as good as any in the world.

Depending on rainfall and other seasonal changes, the tonnage of topped beets per acre is from 11 to 20 tons, an average being about 16 tons, which is superior to most countries.

Tonnage of beets, however, is only a secondary consideration to sugar content, which varies from 1 to 3.5 tons per acre, according to season, an average being 2.5.

Large beets obviously give a greater tonnage but, as a general rule, the medium-sized beet is the best for sugar content and for factory purposes. Two lbs. is an average. The price per ton paid to the farmers is on a strictly sugar content basis.

A little over a century ago the plant yielded about five tons to the acre, with a 5 per cent. sugar content. By the most rigid selection and careful breeding the modern sugar beet now yields 16 tons to the acre, and has a normal percentage sugar content of 15.5, sometimes even reaching as high as 25 per cent. Such beets would naturally revert to a much lower standard very rapidly if not persistently and scientifically selected and cared for. Therefore it is necessary to buy supplies of seed from Germany, Holland and America, where seed production has been brought to and maintained at this high standard. It is a most elaborate and costly business, and until the industry grows it would not be worth while to produce our own seed to any great extent, and is only done by the Department of Agriculture for experimental purposes. Science has perhaps affected the characteristics of the sugar beet more than that of any other known plant.

The beets are watched during the growing season and sampled regularly. When the chemist decides, the beets are harvested. Special ploughs are used to loosen the soil between rows, and the beets are then carefully lifted by hand.

After lifting, the crowns and attached leaves are cut off, and either fed to cattle or ploughed in as manure, both being profitable to the farmer.

A sample load is taken and carefully weighed. Then carefully washed and again weighed. The difference is adhering soil, which is allowed for in all subsequent deliveries.

Arrangements are made to harvest the crop in sections, so that a continuous supply is delivered to the factory over a period of approximately four months.

Much research has been done with regard to the storage of beets, to endeavour to keep beets throughout the year, but
unfortunately by keeping them in silos or dumps they rapidly lose their sugar content. If a satisfactory and cheap method of storage could be devised, the factories could be kept going for 12 months instead of only four months per annum. Possibly some gentleman present might make a suggestion and incidentally a fortune.

The transport facilities for beets could at the Maffra factory be much improved. They are brought by cart, transferred to trucks of the side opening variety, from which they have to be again forked to the beet bins. In America and Europe tractors and trailers are used in the field, whilst the railway trucks are of the bottom opening variety, unloading directly above the bins at the factory, thus saving handling and damage to the beets by forks which occurs at present at Maffra. Damage to the beets, unless they are used immediately, is the cause of many troubles for the chemist, as they rapidly ferment, causing sugar loss.

So much for the beet.

Now for the outline of the process:

The beets are washed and cut into shreds. These shreds are then treated with hot water to extract the juice, which is afterwards treated with lime and carbon dioxide in hot water. The resulting juice is filtered. A second carbonation is then given, followed by another filtration. This juice is treated with sulphurous acid, and afterwards well boiled. Following another filtration, the thin juice is treated in the evaporators to remove water, after which it is boiled in a vacuum pan. The resulting melada is split up into white sugar and first molasses in a centrifugal machine. The white sugar is dried and bagged.

The first molasses is reboiled for a second grade sugar and second molasses. This sugar, which is brown, is mixed with fresh juices and further refined to white sugar.

The second molasses is occasionally reboiled for a third sugar, but if final, is sold as stock food molasses, or used for the manufacture of methylated spirit.

This is in principle very simple, but quite a lot of plant and a great deal of care is necessary at every stage in the process. Naturally most of my remarks will be about the Maffra factory, but from what I know it is quite as up-to-date as most factories except as regards capacity, where it is definitely lacking, as I shall show later.

Let us commence from the delivery of the beets at the factory.

They are delivered by cart from the smaller farms, but there is quite a large proportion which arrives by train. In both
cases they are delivered to the beet bins, which are Vee shaped, the sides being wood lined at an angle of 45°, the top edges being a little above ground level.

Water flumes about 24 inches deep and 12 in. to 18 in. wide are at the bottom of these bins. These flumes are fitted with removable sectional covers, which are removed as required to float the beets into the factory. The water used is from the tail tank of the condensers, and is, of course, warm. The slope of the flumes is about 1 in 100 in the straight sections, but approximately 1 in 80 on curves, which are of large radius.

Just before the flumes enter the factory duplicate sets of stone catchers are fitted to collect stones, horse shoes, nails and the like, whilst on the surface trash catchers deal with all floating matter such as leaves, pieces of wood, etc. One set is used so that the other can be cleaned, for you must remember that this is a continuous process, and therefore anything which stops the flow of the beet or juices reduces the capacity and efficiency of the plant.

As beets are required men remove sections of the flume covers, and allow the beets to float into the factory at the speed required. A simple system of signalling from within the factory adjusts the flow.

The flume terminates at the beet wheel, which is a large steel structure about 15 feet diameter, comprised of a solid disc which carries a series of radial perforated plates forming a bucket type elevator. The beets are thus lifted and drained before dropping into the washing machine, which is a very simple piece of apparatus. The machine is about 15 feet long, and is slightly inclined. The bottom is of semi-circular section perforated steel plate. Radial arms of propeller section are fitted to a heavy steel shaft which revolves at about 10 r.p.m., whilst warm water is being constantly sprayed on the roots, which travel as they are washed. The washed beets automatically feed into the beet elevator of the bucket type. This elevator feeds into the hopper of the slicing machine, passing on its way yet another means of eliminating nails, etc. Immediately before passing into the hopper the beets are weighed on a continuous weighing machine. This is a very important item, as it is very necessary to obtain accurate figures if good chemical control is the aim. The scale most used is the "Chronos" Scale, made by the Hennefer Maschinenfabrik, although several other excellent scales are now on the market. Occasionally these are checked by another scale.

Prior to 1860 beet juice was extracted by rasping the roots and subjecting the pulp to heavy pressure, exactly as in the
case of cane juice extraction, but this was a very wasteful method for beet.

The beet slicer is generally of the vertical spindle type, with a horizontally revolving cutter plate. These plates carry Vee shaped knives in sections interspersed with slots. The weight of the beets in the hopper creates sufficient pressure for slicing. The slices are Vee shaped so that in the next process they will not pack, and thus prevent circulation of juice. The particular shape of knife is the result of many years of experiment.

These machines are made in various diameters, the limits being four feet to eight feet. The maintenance of the knives for the Maffra factory requires the full time services of a fitter, in spite of great precautions to eliminate stones, nails, etc.

The resulting slices are called cossettes, which fall through the slots between the knives into another hopper, and are dealt with by a scraper conveyer.

The conveyer is arranged over the battery of diffusion cells which extracts the juice. In the Maffra factory there are 14 cells, 12 in use, one filling and one emptying. The conveyer is fitted with deflectors and chutes at various points for filling the cells.

In 1821 Matthieu de Dombasle invented the diffusion battery system, but it was not until 1860, when Robert combined it successfully with Rousseau’s 1849 invention of the carbonation process (which latter was perfected by Perier and Possez in 1859), that real progress in beet sugar manufacture began.

If one adds water carefully to a strong sugar solution, the water will rest upon the latter. Diffusion takes place at the points of contact, until after a sufficient lapse of time the sugar will have become uniformly distributed in the liquid.

The same thing occurs slowly when two liquids are separated by a membrane, but the rate of diffusion varies greatly with different substances. Those which diffuse rapidly are crystallisable and are termed “Crystalloids,” salt and sugar for example. Others which diffuse slowly or not at all are known as Colloids, albumin for example.

If a liquid containing both sugar and albumin be placed on one side of a membrane and pure water on the other, the sugar will pass through and leave the albumin behind. This method of separating a crystalloid from a colloid is called “dialysis,” and the separating membrane the “dialiser” or septum. The process is entirely different from filtration, for the substances are both in solution.

The minute cells of plants are composed of vegetable membranes, which act as dialisers.
During the plant’s growth the sugar manufactured in the leaf passes into the other parts of the plant through these membranes or cell walls until each cell is rich with sugar.

In order to extract this stored sugar, the process is simply reversed, and this principle is used in

The Diffusion Battery.

This is a battery of ten to fourteen cylindrical containers, into which the beet slices are filled. As diffusion takes place more rapidly with hot water, this is used for the extraction of the sugar from the beet.

The principle of working is as follows:—The cylindrical container is filled with cossettes (or beet slices), and then filled up with hot water. Diffusion will at once commence, and the easily soluble sugar juices will part from the beet cossettes and distribute itself equally in the beet and the water, 50 per cent in each. This water is then drawn off, and a fresh supply added to the cossettes, which will extract a further 50 per cent of the 50 per cent—25 per cent remaining in the cossettes. This water is then drawn off and another fresh supply added, and so on. As each fresh supply of water halves the remaining sugar in the beet, ten fillings will extract all but .098 per cent of the sugar contained in the beet, and twelve fillings in all but .024 per cent (as in the Maffra factory) sugar content thrown away in the shape of spent cossettes. This juice is very much purer than that obtained in the old system of rasping the beets and crushing out the juice, for it eliminates the unwanted colloids. This system was carried out for some time, but it was found to give a large quantity of thin juice which was costly to evaporate.

Between each cell of the modern battery is a calorisorator, which keeps up the temperature of the juice to a certain figure, about 60° C. It is necessary for quick diffusion to heat the water, but this makes very active many different bacteria which are present in the beets and to the soil adhering to them. Many of these are destructive to sugar, but at 60° C. they are either destroyed or rendered inactive. The more quickly this heating is done the better, and the smaller quantity of diffusion juice on the way from the battery to the carbonation tanks the smaller are the chances of destruction of sugar. The present method of working a battery is as follows:—

Hot water enters No. 1 cell under pressure, and diffusion takes place, the juice passing onward through the calorisorator (to maintain the temperature) to No. 2 cell, and so on. After reaching No. 4 or 5 cell, diffusion ceases owing to having
reached a point where the juice is of practically the same concentration as the cossettes in that cell. At this point a measured quantity is extracted, allowing fresh hot water to enter No. 1 cell. This reduces the concentration in all these cells, so that diffusion can again continue. No. 6 cell has, by this time been filled, and is added to the circuit. This continues until 12 cells are in commission, after which all the sugar has been extracted from No. 1 cell cossettes. These are then blown out through the bottom of the cell by compressed air entering the top, after the cell has been isolated from the system. Thus there is a juice produced which is of maximum concentration.

The spent cossettes are dropped into a concrete trough, from which, at the Maffra factory, they are sent by a centrifugal pump to the beet pulp silo, where the mass is drained and stored for use as cattle food. The silo is 450 ft. long and 90 ft. wide, with earth sides 10 ft. high. The whole is wood lined and drained to the river.

Maffra is, of course, fortunate because most factories have to install a plant for compressing and drying the pulp. It is generally dried to a point where its moisture content is about 16 per cent.

The Maffra diffusion cells are approximately 4 ft. 6 in. diameter by 15 ft. high by \( \frac{1}{2} \) in. thick, with conical screen plates fitted at the top and bottom with 5/16 in. holes at 9/16 in. pitch. Chains are fitted in two places towards the lower end to prevent the too close packing of the cossettes which otherwise interferes with juice circulation, which (by the way) is upwards in the cells and downwards through the inter-cell calorisators. These calorisators are vertical, and approximately 9 ft. 6 in. between tube plates and 10 in. diameter with 12 2-in. brass tubes giving 50 square feet heating surface.

The diffusion juice, which is slightly acid, is pumped through a pulp catcher to the measuring tank, which is divided so that one half can be filling whilst the other is supplying the first carbonation through a juice heater. This juice has a specific gravity of 1.048 to 1.063, and rapidly darkens on exposure to air.

Let us now examine the lime kiln. This is of 1600 cubic feet capacity. The quicklime is slaked in a special machine with a stirring mechanism, and the milk of lime is about 20° Baumé, the sweet water from the filter presses being used for the purpose. This milk of lime is circulated by means of a pump continuously so that no settling can occur, the required quantity being measured and added as required at the carbonation tanks. After the addition of the lime, carbon
dioxide is pumped through the juice from the lime kiln. This is the carbonation process, which is not really fully understood yet even by chemists (according to such a well-known authority as Dr. Franz Murke). The process, however, forms a granular precipitate of calcium carbonate. Lime is the purifying agent, precipitating the non-sugars from the juice. Carbon dioxide is the neutralising agent, which precipitates the excess of lime and the resulting carbonate facilitates filtration. This carbonation process is carried out at a temperature of 70° to 80° C. If above this temperature the juice causes endless trouble by frothing, whilst if much below the carbonated juice is most difficult to filter. A simple paddle stirring gear is fitted to each tank, but much of the stirring is done by the carbon dioxide bubbling through their distributors.

The process is continued until a point is reached when all the sugar can be extracted in the first filter presses. If the process is continued too far, soluble matter other than sugar is passed over that cannot be filtered, such as calcium bicarbonate, which after yielding up its carbon dioxide gas in the evaporating process deposits scale on the heating surface of the evaporators, which causes bad sugar work and trouble for the engineers later.

A rough test of the completion of carbonation generally is to take a sample in a test tube. The precipitate should subside gradually, and leave the juice transparent and light in colour. If subsidence be very slow, carbonation is not complete. If rapid, and clear juice is dark, over carbonation has occurred. Towards the critical point the chemist has a more critical test.

Immediately before being pumped through the first filter presses the juice is heated to 95° C. by steam coils in the bottom of carbonation tanks, or better still by being pumped through a heater as at Maffra.

The carbonation tanks have a working capacity of 6 per cent to 7 per cent of the quantity of juice treated per 24 hours. As frothing occurs to a considerable extent however, it is now the general practice to allow about 10 ft. of open space in the tank above the working level of the juice. Each of these tanks at the Maffra factory is 18 ft. high by 9 ft. by 7 ft. Even with that height, I have on occasions seen froth issuing from the overflow pipe about 12 ft. above these tanks, but this is generally due to starting up after Sunday stoppage. In most other countries the mills work continuously, and Sunday stoppage is quite a difficulty, as miles of pipe must be thoroughly cleaned out before stoppage to prevent fermentation and other troubles when recommencing.
The juice being pumped through the heaters goes directly to the first filter presses, of which there are four, two being in use and two being cleaned. Each of these in the Maffra factory has 550 square feet filtering area. Pressure gauges indicate when the press is full, and the stream of juice practically ceases. The presses are of special design, enabling the filter cake to be washed with hot water to collect all available sugar content.

A special washing machine for the filter cloths is a vital part of the plant, the sweet water being used for slaking the lime so that all available sugar returns to the system. Care must be taken to see that all holes in the filter cloths are darned, and even then the average life of a cloth being only about a week, it can be seen that this is one of the most costly plant items.

The lime mud from the presses is not used at Maffra, but it obviously contains substances taken from the earth, but is only a poor quality fertiliser. It, however, contains small amounts of phosphoric acid and nitrogen. It is said to be beneficial to heavy soils.

The juice is then fed to the second carbonation tanks, where a similar process to the first carbonation takes place, lime being added sometimes and carbon dioxide pumped through the juice. From this point onwards the juice must be kept as hot as possible. More care is taken with the second carbonation than with the first, as it is here than any correction is made.

Again the juice is pumped through a heater on its way to the second carbonation filter presses. As there is much less solid matter to filter, the presses need only have about one-third the filtering area of the first presses. Again the juice is collected, and the precipitate washed clean of sugar before the presses are opened.

The juice at this stage, which has an alkilinity of .015 to .025, is taken to a sulphur tank, where it is treated by pumping sulphurous acid through it, this being obtained from a stove burning sulphur, the outlet pipe from the tank being taken as high above the roof as possible.

There seems to be a difference of opinion as to the state of this juice, some chemists bringing this to a neutral state, others preferring to keep it alkaline, as a neutral juice easily turns acid.

After the sulphur tank at Maffra, the juice is given a thorough boiling in the thin juice boiler. This is 5 ft. 4 in. in diameter by 12 ft. 7¼ in. high, 232 2-in. brass tubes, 3 ft. 6 in. long x 12 g. 15 in. central tube; 4 ft. 4½ in. outside calandria
heater: 400 square feet of heating surface. The juice is afterwards pumped to the Thin Juice Tank, after which it is filtered in Danek bag filters, from which it goes to the supply tank for the evaporators. This thin juice, obtained from 1000 lbs. of beets, weighs approximately 1400 lbs. The thin juice is converted to thick juice weighing about 280 lbs. by means of evaporation of water. Now the cost of this would be enormous if it were not for triple, quadruple or quintuple evaporators. The latter is used at Maffra. By this means approximately 4.7 lbs. of water can be evaporated per lb. of steam used. The first body is heated by exhaust steam from the factory. If this is not sufficient, live steam must be added. The steam enters the heating chambers of this first body and is condensed into water, giving its apparent and latent heat to the juice in the juice chamber, which absorbs the heat and evaporates a corresponding amount of water. The vapour produced from the juice enters the heating chamber of the next body, which in turn evaporates the water from the juice in that body. And so on, until the vapour from the fifth body is taken to a condenser, where it is condensed into water by the injection of cold water, a vacuum pump being used to extract the air and any other uncondensable gases, such as ammonia and carbon dioxide.

At the Maffra factory No. 1 Evaporator body was made by Messrs. Kelly and Lewis, and was added during the reconstruction in 1926. It is 10 ft. 6 in. diameter, and approximately 15 ft. high. It is, like the existing bodies, a calandria type evaporator with 1630 2-in. brass tubes at 2½ in. pitch, 4 ft. 1½ in. between tube plates. Juice inlet and outlet 5 in. diameter, vapour inlet 14 in. diameter, vapour outlet 18 in. diameter, 9 ft. parallel height above top tube plate. The heating surface is 3400 sq. ft. It is of cast iron, and weighs 20 tons.

The Nos. 2, 3, 4 and 5 Bodies are part of the old plant, the dimensions being as follows:—7 ft. 2½ in. diameter body, 9 ft. 10 in. above tube plate, 4 ft. 1 in. between tube plates. 920 2 in. brass tubes. Heating surface 1900 sq. ft.

The thick juice resulting from evaporation has a density of approximately 60 Brix., and a temperature of 60° to 65° C. In the evaporators not only the sugar but also the non-sugars have become concentrated. In regard to the latter, the concentration has become so great as to precipitate part of the non-sugar substances. Thick juice from the evaporators has not only eliminated the water, but has also participated in the after purification of the juices. When this juice is heated an additional amount of the non-sugar substance is precipitated, and therefore an essential part of the
process at this point is to pass it through an efficient heater. The high temperature thus obtained precipitates the non-sugars, and gives a more crystalline precipitate which can very easily be filtered later.

The thick hot juice is pumped to the remelter, which is the junction where "High Wash" from the centrifugals is added together with brown sugar from the second sugar pan. The resulting mixture is called Standard Syrup. This syrup is in most factories again treated with sulphurous acid in the thick juice sulphur tank, as the juice is still alkaline, and must be corrected to an alkalinity of about .01 to .02. This sulphur treatment, as with the first sulphuring, bleaches the juice. Both the sulphur processes are together, the same sulphur stove serving both. This is a very important stage, and is carefully watched by the chemist. The juice is again heated to assist easy filtration, which takes place in Danek bag filters.

These filters, at the Maffra factory, each contain 23 frames 2 ft. 2 in. square. The strainers are of perforated copper 3 in. diameter, with 11 5-mm. holes per square inch. The resulting juice is pumped to the pan storage tank, which supplies the White Sugar Vacuum Pan.

At the Maffra factory this pan is 10 ft. diameter, with a "strike" capacity of 665 cubic feet. The heating surface is 836 square feet, being 1.25 square feet per cubic feet of massecuite or "melada" or "fillmass." The heating coils are of 4 in. diameter copper pipe.

Besides effecting a large saving in steam, the boiling of the juice in a vacuum is necessary to prevent the burning of sugar. I watched an expert sugar boiler from Queensland at Maffra, and the following was his process:

The juice is drawn into the pan and one set of coils after another, beginning with the lowest, is brought into use. After the third coil is brought into use, and about a half to three-quarters of an hour after starting, the mass begins to "grain." The sugar boiler then carefully watches and tests the massecuite very frequently, and brings on the fourth after about one hour from starting. Approximately twenty minutes later the fifth coil commences, the sixth half an hour later, the seventh half an hour after that, after which the boiling continues for about three-quarters of an hour. When he decides that everything is in order, the steam in the coils is turned off, and the whole mass, which is called massecuite or melada, is dropped through a large treacle type valve into a mixer. The boiling process takes about three hours, and calls for the highest skill.

The mixer is a large horizontal one with semi-circular section bottom, a double ribbon-stirrer revolving at about
one r.p.m. is provided to keep the whole mass from setting solid. The mixer is placed immediately over the centrifugal machines. At the Maffra factory there are four white sugar machines. These have 40 in. diameter baskets, which run at 1100 r.p.m. A load is dropped from the mixer down a special revolving type chute whilst the machine is running. This is spun for about six minutes, the first molasses being spun off and collected in a tank through a chute. There still remains, however, a residue of sticky molasses which is washed off the sugar by means of a spray of hot water, which is only kept on sufficiently long to remove the molasses without melting the sugar. Whilst this process is going on, the outlet is switched over to another chute leading to another tank. This liquid is known as “High Wash,” which is pumped back to the “Re-melter.” After washing, the centrifugal continues spinning until all possible moisture is eliminated there.

The machine is then stopped, and the conical bottom opened to drop this “Wet Sugar,” as it is called, into a scroll conveyor. At the Maffra factory this leads to a bucket elevator which delivers into the sugar hopper. This is large enough to contain 20 tons of sugar, and is constructed of wood lined with galvanised iron, with very steeply-sloping pyramid bottom. In this bottom is fitted a small machine, which feeds the wet sugar into the Granulator. Most granulators are of the “Hershey” type, which is a long, slightly inclined, revolving drum, the interior of which is divided into a large number of pockets. At the lower end of the drum are three screens, the first of which is fine enough to sift sugar dust; the second, standard sugar; the third, lumps of candied sugar (of which children of all ages are very fond).

A longitudinal steam pipe provides the necessary heat at Maffra, whilst a fan and heater blowing at the lower end are used to circulate dry air through the granulator. The outlet passes through a sort of trap tank before being taken through the roof. This trap collects the sugar dust (which, by the way, is highly explosive). No naked lights are allowed in a granulator room because of this dust. The latest granulators are not provided with a central pipe, a large fin heater and fan providing sufficient heat for the process, whilst eliminating most of the candied sugar lumps which form on a central pipe.

The sugar dust and lumps, if not sold, are returned to the Re-melter. These are, however, a very small proportion of the total. The standard sugar drops into a special chute leading to the bagging scales. The bag contains 70 lbs., which are delivered to the warehouse to await shipment.
The sugar warehouse, if it has a galvanised iron roof, must be lined in such a way as to eliminate any possibility of moisture, due to condensation on cold mornings, dropping on the bags. The floor, if of concrete, should have a wooden platform to allow of circulation of air under the stacked bags. Any moisture on the floor which happens to touch one bag quickly spreads to others, as dry sugar has a great affinity for water.

Let us now go back to the "First Molasses," or "High Green" as it is often termed. This has a sugar content of about 86-87 per cent, and is taken to the pan storage tanks which supply the Raw Sugar Vacuum Pan. The boiling is a very long process, varying from five to 14 hours. When the sugar boiler considers this has commenced graining, he drops the second fillmass from which it is taken to one or other of a battery of crystallisers.

In former times this fillmass was dropped into small tanks, in which it cooled off very quickly, thus forming a large amount of fine grain sugar. Such a fillmass could not be concentrated at as high a temperature as is possible with the modern crystalliser.

These crystallisers are generally long, cylindrical, horizontal containers, mostly steam-jacketed at the bottom, and provided with ribbon mixers which slowly revolve. The temperature is kept high enough so as to just not burn the sugar, and the mass is kept in motion for about 72 hours, during which the fine grain crystals formed in the second Vacuum Pan increase in size. At Maffra there are six of these machines, each approximately 15 ft. long by 6 ft. diameter.

After this process the mass is dropped into the Raw Sugar Centrifugals, from which is spun a second molasses. This raw sugar is brown in colour, but is not used for food as is the corresponding sugar from the cane process, due to its containing earthy matter. The sugar is not sold, but is immediately returned to the re-melter. The final molasses is pumped to the storage tank (which at Maffra is 30 ft. diameter and 25 ft. high). This is sold for the manufacture of cattle food or methylated spirits. According to Dr. Franz Murke, an average output of molasses in a white sugar factory is about 5 per cent to 6 per cent of the beets, with 2.5 to 3 per cent of sugar. Now this sugar is certainly worth saving. There are several methods of accomplishing this purpose. The simplest method is the feeding of the molasses to stock. In this way the potash salts of the molasses are added to the manure and returned to the land. Feeding with pulp and molasses in combination is perhaps the simplest way of returning the equivalent of the lost sugar to the land in which it was grown. But economies
steps into the question, and therefore where food is cheap it pays better to extract this sugar from the molasses. There are numerous methods of doing this, but only three have proved successful. These are known as the Osmose process, the Steffen's process, and the Strontium bisaccharate process. This latter process is only used in Germany where it was first used, and has been developed to a high degree of efficiency. In all other countries practically the only process now used is the Steffen's process. The small quantity of molasses produced in a factory such as that at Maffra hardly warrants the expense of a Steffen's House, but in factories where 750 tons of beet and upwards are cut per day this is standard practice. I have not seen a Steffen's plant in action, but it was described to me by Mr. A. J. Hebert, who was the reconstruction engineer at the Maffra factory. Here is a brief description:

The second molasses is pumped, weighed, and diluted, and a small quantity of milk of lime added. This solution goes to a tank to be cooled, after which it is pumped to the "coolers." About 1600 lbs. of thinned solution enters a cooler at a time. Here powdered lime is added. There was previously great difficulty in obtaining finely-powdered lime, but this difficulty has now been overcome by means of jaw crushers and enclosed mills, from which the powdered lime is extracted by means of a fan. The same air is used over and over again, thus preventing moisture entering the circuit, which would partly slake the lime.

The coolers are about 7 ft. 6 in. diameter. In the centre of the tube plates is a central well, 3 feet diameter, in which a propeller revolves at 180 r.p.m., forcing the liquid down. The liquid returns, of course, through the 7 ft. long 2½ in. tubes. In all except quite cold countries it is necessary to have a refrigeration plant to keep the circulating brine cold enough to prevent the lime slaking during the process.

Special care is taken that the cooler is filled to the correct depth, which is determined by experiment. The maximum temperature at which calcium trisaccharate is formed is about 25° C. The lime addition in a modern Steffens plant is approximately 100 per cent of the sugar in the molasses.

It may be of interest to mention that the stuffing box packing is rawhide, that being found best to resist the chemical and grinding action of unslaked lime. Lime is added until the waste water contains 0.5 per cent of sugar, then the cooler is emptied into receiving tanks, from which it is pumped to the saccharate presses. The saccharate from the coolers settles if left standing, so that it is necessary to keep it in continuous circulation until pumped to the presses, all dead ends and long pipes being avoided.
The saccharate presses are of different design to the carbonation presses, as the saccharate is much easier to filter than is lime mud. The cavities are therefore much larger, a thickness of two inches being generally adopted. Great care is necessary in using these presses, as it is quite easy to break the frames if the channels, frames and plates are not kept clean. Care must also be taken that filter cloths are not doubled at places. Operators find that their work is much easier if they adhere to strict cleanliness. Forty pounds per square inch indicates that the press is full. The washing process is slow to obtain maximum sugar, a pressure of 20 lbs. for about 40 minutes being the usual procedure. The filter cloths of these presses are generally of coarse jute, and last one to two weeks. Unlike the carbonation cake, which is thrown away, the saccharate filter cake contains sugar. It is dropped into a hopper, which carries it to the saccharate receiving tanks, where it is thinned to a milk with the sweet water from the hot filter presses. This milk is pumped to the carbonation tanks, taking the place of the milk of lime used at factories where no Steffens process is installed. Before use it is heated.

The average true purity of the saccharate in a Steffens house is about 87, the average true purity of the Steffens house molasses is about 64. The losses in a Steffens house in waste water may be 8.5 per cent. of the sugar in molasses. The practical results show an extraction of 66.5 per cent of the sugar in molasses, 25 per cent sugar in resulting molasses, and 8.5 per cent loss—i.e., eight-twelfths of the molasses sugar in granulated, three-twelfths sugar in resulting molasses, and one-twelfth sugar lost.

There is a limit to the degree of purity which the tri-saccharate can attain. Purity depends on the nature of the molasses and of the substances precipitated by the lime from this molasses. Such non-sugar substances are partly decomposed again in the carbonation process, go into solution and form molasses again. The continuous circulation of these substances reduces the efficiency of the plant, and makes it necessary to discard molasses after about four to six weeks at the beginning of the campaign, and perhaps every two to three weeks towards its close. It varies in different countries and in different soils. The only sure indication is the impossibility of obtaining the normal degree of purity under otherwise unchanged conditions. Fermented beets are probably the cause of most of the non-sugar substances. If beet sugar factories are comparatively close together, it is a normal proceed-
Boiler House.

There are a number of places where it is possible for sugar to enter the boiler feed water, and this has to be watched very carefully. A little sugar apparently is not injurious as long as the water is slightly alkaline, but where large amounts of sugar enter, the water will take on a deep brown colour, and will foam. The escaping steam has a very characteristic odour. The only remedy is to blow down the boilers and fill up with fresh water.

Needless to say, whenever sugar is present in the boilers, its source must be located and leaks repaired at once to prevent a repetition. Leaky tubes in the evaporators, leaky coils in the vacuum pans are the most likely places to find trouble. Quite a common method of retaining a slightly alkaline boiler water is to add soda ash. Boiler water is always tested for sugar by the chemist three times a day. Another trouble in sugar factories is lubricating oil from the engine cylinders getting into the sugar process. This is generally prevented by a slight overflow of the boiler feed tank, either continuously or at regular intervals. Some factories use oil separators in the exhaust steam line before it enters the evaporators.

Quite an elaborate steam trap system is required, most of the condensate from the factory is returned to the boilers. The water consumption in a beet sugar factory runs into big figures. For a factory cutting 1000 tons of roots per 24 hours, and using a quintuple effect evaporator, nearly 3,500,000 gallons of water are required, or 2350 gallons per minute. Therefore the obvious place for such a factory is beside a river. This quantity is used as follows:

- 660,000 gallons for diffusion
- 820,000 gallons for evaporator condenser
- 1,110,000 gallons for white pan
- 570,000 gallons for second pan condenser
- 220,000 gallons for miscellaneous purposes

3,380,000 gallons total

By spray cooling, etc., much of this water can be used over and over again, and thus if necessary approximately 50 per cent can be saved if a river is not available.

The sewer water from a beet sugar factory is composed, first, of the water from the flumes and beet washers. To this nobody could make any objection as it is merely soil in suspension, together with a few weeds and bits of beet, which can be easily dealt with in a settling pond. This is the bulk of
AN OUTLINE OF BEET SUGAR MANUFACTURE.

the water. Secondly, there is the diffusion pulp water. This is a little more objectionable, but a river of any size quickly purifies this small percentage. The Steffens House water is such a small percentage that no objection is made by any authorities to its inclusion in the waste water to a river. This water, however, contains valuable salts, which some factories recover and sell as a by-product. It is sometimes mixed with the pulp water for irrigation purposes.

A complete purification of the sewer water of a beet sugar factory has not yet been accomplished, and may not be possible.

A word or two about the Maffra factory may be of interest. This plant can deal with 475 tons of roots per 24 hours. It was built about 38 years ago, was idle for 10 years, and has been operated by the Department of Agriculture since 1910.

Until 1915 it was run at a loss, but since that time has made good profits, except in 1919 and 1928, and has made a total profit for the State of approximately £250,000.

<table>
<thead>
<tr>
<th>Year</th>
<th>Loss</th>
<th>Profits</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>£8,014</td>
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<tr>
<td>1917-18</td>
<td></td>
<td>1,868</td>
</tr>
<tr>
<td>1918-19</td>
<td>£1,782</td>
<td></td>
</tr>
<tr>
<td>1919-20</td>
<td></td>
<td>16,750</td>
</tr>
<tr>
<td>1920-21</td>
<td></td>
<td>5,276</td>
</tr>
<tr>
<td>1921-22</td>
<td></td>
<td>9,920</td>
</tr>
<tr>
<td>1922-23</td>
<td></td>
<td>13,290</td>
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<td>1923-24</td>
<td></td>
<td>19,017</td>
</tr>
<tr>
<td>1924-25</td>
<td></td>
<td>23,142</td>
</tr>
<tr>
<td>1925-26</td>
<td></td>
<td>3,529</td>
</tr>
<tr>
<td>1926-27</td>
<td></td>
<td>855</td>
</tr>
<tr>
<td>1927-28</td>
<td>6,949</td>
<td></td>
</tr>
<tr>
<td>1928-29</td>
<td></td>
<td>5,654</td>
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<td>1929-30</td>
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<td>17,341</td>
</tr>
<tr>
<td>1930-31</td>
<td></td>
<td>52,366</td>
</tr>
<tr>
<td>1931-32</td>
<td></td>
<td>19,418</td>
</tr>
<tr>
<td>1932-33</td>
<td></td>
<td>56,209</td>
</tr>
</tbody>
</table>

£8,731 £252,649

It is generally agreed that for economical operation a 500-ton factory is the minimum size. The majority of American mills treat 1000 tons per day.

For a 500-ton factory the following are interesting figures:—
Water required, 2,500,000 gallons per day; coal required, 4500 tons per season; lime rock required, 2000 tons per season. In addition, large quantities of sugar bags, filtering materials, coke and other factory needs must be supplied.
The site should be central to the beet growing area, and have a railway siding. A flat country could use the waste waters from the factory with advantage through irrigation channels.

The factory should have control of 4000 acres of land for beet growing.

The rainfall should be good, or a good irrigation system should be provided. Such a mill would provide direct employment for 700 men in field and factory, as well as large numbers indirectly.

The whole of the plant could be manufactured in Victoria, and would be quite a help to our local industry.

The Department of Agriculture has done a great service to the industry in this State, and the results of their valuable experience can be had for the asking. It is remarkable that the confectionery manufacturers of this State have not established the industry for themselves. By doing so they would be assisting farmers, engineers, and a host of others.

The deep tillage required for beet growing improves the land, and beet is an excellent rotational crop between wheat growing.

The beet sugar industry has had a very chequered career. In 1811 France took up the new industry, and from France it spread to other countries. Napoleon gave it a great impetus, seeing at once the advantage of producing sugar at home. The blockade raised sugar to famine prices, so the new factories flourished. Forty were in operation in 1812, and produced 10,000 tons of sugar. When the blockade was raised, however, prices fell, and the industry had a bad time. About 1830 there was a big fall in the price of corn, and the farmers again turned to sugar beet.

By the year 1854 Europe produced 200,000 tons of beet sugar. Ten years later the figure was 500,000 tons. In 1871 it exceeded one million tons, and in 1881 the figure was nearly two million tons. The time came when half, and, later, two-thirds, of the world's sugar was produced from beet.

The story of how the industry flourished by the very wise actions of the German Government is a very long one.

The taxes on the roots were designed to be an incentive to the farmers to grow richer roots, and the engineers to design better plant to produce more sugar from the roots. The system, as usual in Germany, was a great success.

France, on the other hand, taxed every ounce of sugar produced, thereby crippling the industry. She produced no more sugar in 1884 than she did in 1871, but Gemany's production
went up in the same period from 186,000 to 1,123,000 tons, and the extraction from the roots from 8.28 per cent to 11 per cent.

In France it remained at 6 per cent, but when she changed over to a duty on the roots the extraction quickly rose to 7, 8, 9, and 10 per cent. In 1896 France managed to reach 11 per cent, but with a ten years’ start the Germans had by that time reached 12.66 per cent.

United States of America began in 1890 to seriously embark on the beet sugar industry, and twenty years later 63 factories were working.

Practically every country in the world with a temperate climate has beet sugar factories, and the sugar extraction has reached an average of about 15 per cent.

The industry has not had all its own way of course, because the cane industry had to improve its methods for self-preservation reasons. This gave it a new lease of life.

To-day the cane and beet industries are working hand in hand, each having its own sphere, 33 per cent from beet sugar being the average for 1923-1933 period. The total yearly production of the world’s sugar is approximately 18 million tons. Both industries deserve to prosper after their splendid efforts in the past.

I have to thank the Director of Agriculture, and my friend, Mr. Pywell, the Manager of the Maffra factory, for much valuable assistance in the preparation of the samples and recent production and profit figures.

**DISCUSSION**

The President said that Mr. Dobson had given a very interesting outline of the beet sugar industry—one which was now earning a return for the State.

Mr. A. C. Mitchell congratulated the author upon his paper, and asked if any progress had been made in the storage of the beets so as to make it possible to work the plant throughout the year. In addition to the economic advantages of full-time running, this would encourage a greater production of beet.

Mr. J. A. Naismith asked whether there was any chance of the sugar getting into the boiler, and whether the hot water could not rather be used in other parts of the plant.

Mr. W. R. Pollock asked how the cost of production of beet sugar compared with that of cane sugar.

Mr. A. I. Hosie asked by what means the crystal size was controlled.

Mr. J. Ahearn said the paper had been most thorough and lucid. He understood that at Maffra an irrigation scheme had
been undertaken. How had that scheme affected the quality of the beet?

Mr. WM. H. Dobson, in reply, said the beet could be stored in silos quite well, but there were disadvantages. The only good method of keeping beet, and that for only a limited time, was to place it in piles of approximately eight feet wide by four feet high, and not more than twenty feet long, and cover with earth, but the beets must be frequently dried and the adhering soil removed. The beets could also be stored in bins, but in the humid atmosphere of the bin growth commenced similar to that which occurred when potatoes were stored; thus, some of the sugar was consumed. If the warmth increased rotting commenced, and quickly permeated the whole mass. He understood that experiments were being made in Germany of cutting the beets into cosettes, drying them in a special drier, and storing the product. The beet was a tender plant, and if the outsides of the heaps were not properly covered, the beet was easily frostbitten, which would in turn cause rotting. In answer to Mr. Naismith—the sugar could only get back to the boiler through a leaky or broken coil. Regarding the overall cost of beet sugar, it was interesting to note that in England seventeen large beet factories had recently been built. But in Australia, with its well-established cane industry, he thought there was much in its favour, although the beet could compare favourably here with the cane. The size of the crystal grain was controlled by the manner of boiling, the larger crystals being due to longer boiling. The usual granulation required about three and one-half hours. Regarding the effect of irrigation, the figures in the Appendix did not indicate any deterioration in quality.

The President, in moving a vote of thanks to the author, said the paper represented a vast amount of work and time spent in its preparation. It was very gratifying to note that the Institute had received such a valuable paper from one of its most recent members.

Mr. R. J. Bennie said he had great pleasure in supporting the vote of thanks, for the paper was a most valuable record of the work of a great industry. Mr. Dobson had made a thorough survey of the whole process in all its phases—from the agricultural to the engineering aspects. He felt that the Institute should recognise the promptness with which Mr. Dobson had honoured the obligation, which all new members are supposed to undertake, of contributing a paper within a reasonable time, and he hoped that it would encourage others to emulate him.
**APPENDIX**

**MAFFRA SUGAR FACTORY RECORD.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Acres harvested</th>
<th>Tons of beet</th>
<th>Price paid</th>
<th>Tons of sugar content</th>
<th>Per cent white sugar content of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1911</td>
<td>458</td>
<td>5,970</td>
<td>13</td>
<td>16/-</td>
<td>482</td>
</tr>
<tr>
<td>1912</td>
<td>752</td>
<td>3,975</td>
<td>5.33</td>
<td>25/4</td>
<td>519</td>
</tr>
<tr>
<td>1913</td>
<td>900</td>
<td>6,208</td>
<td>6.9</td>
<td>20/-</td>
<td>648</td>
</tr>
<tr>
<td>1914</td>
<td>1,000</td>
<td>7,432</td>
<td>7.4</td>
<td>23/-</td>
<td>920</td>
</tr>
<tr>
<td>1915</td>
<td>990</td>
<td>8,843</td>
<td>8.9</td>
<td>23/-</td>
<td>1,182</td>
</tr>
<tr>
<td>1916</td>
<td>461</td>
<td>4,928</td>
<td>10.7</td>
<td>25/-</td>
<td>560</td>
</tr>
<tr>
<td>1917</td>
<td>1,320</td>
<td>15,159</td>
<td>11.5</td>
<td>27/6</td>
<td>1,948</td>
</tr>
<tr>
<td>1918</td>
<td>1,200</td>
<td>14,487</td>
<td>12.1</td>
<td>27/6</td>
<td>1,650</td>
</tr>
<tr>
<td>1919</td>
<td>1,000</td>
<td>12,289</td>
<td>12.3</td>
<td>27/6</td>
<td>1,263</td>
</tr>
<tr>
<td>1920</td>
<td>1,080</td>
<td>13,084</td>
<td>12.2</td>
<td>35/-</td>
<td>1,551</td>
</tr>
<tr>
<td>1921</td>
<td>1,180</td>
<td>7,147</td>
<td>6.1</td>
<td>45/-</td>
<td>833</td>
</tr>
<tr>
<td>1922</td>
<td>1,602</td>
<td>16,578</td>
<td>10.3</td>
<td>45/-</td>
<td>1,872</td>
</tr>
<tr>
<td>1923</td>
<td>2,045</td>
<td>20,444</td>
<td>10</td>
<td>42/6</td>
<td>2,784</td>
</tr>
<tr>
<td>1924</td>
<td>1,937</td>
<td>29,512</td>
<td>15.3</td>
<td>37/6</td>
<td>3,499</td>
</tr>
<tr>
<td>1925</td>
<td>1,897</td>
<td>24,468</td>
<td>13</td>
<td>40/-</td>
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</tr>
<tr>
<td>1926</td>
<td>1,880</td>
<td>21,194</td>
<td>11.2</td>
<td>40/-</td>
<td>2,315</td>
</tr>
<tr>
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<td>9,851</td>
<td>4.9</td>
<td>40/-</td>
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<td>1928</td>
<td>2,353</td>
<td>25,439</td>
<td>10.8</td>
<td>42/6</td>
<td>2,349</td>
</tr>
<tr>
<td>1929</td>
<td>2,130</td>
<td>15,236</td>
<td>7.2</td>
<td>43/-</td>
<td>2,108</td>
</tr>
<tr>
<td>1930</td>
<td>2,500</td>
<td>26,525</td>
<td>10.6</td>
<td>—</td>
<td>3,472</td>
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</tbody>
</table>

With reference to the last column, the real sugar content of the beet also includes that in the molasses. For example, in the year 1928 the percentage white sugar obtained was 9.2, but the total sugar content was in this bad season 12.56 per cent. In the season 1923 the sugar content was approximately 18.5 per cent. A normal season gives approximately 11.4 per cent. white sugar, with a total sugar content of 15.5 per cent.
DISCUSSION—(Continued).

AN OUTLINE OF BEET SUGAR MANUFACTURE.

Paper by Wm. H. Dobson.

Mr. A. E. Bell asked if other areas of Victoria had been tested as to suitability for beet cultivation, also whether it was feasible to obtain power alcohol as a by-product.

Mr. Dobson replied that Warrnambool was considered to be better than Maffra. The Department of Agriculture had found several areas to give excellent results. The factory must be near a good water supply.

Mr. E. H. G. Morris said that regarding the question previously raised as to the possibility of molasses finding its way into the boiler, no serious harm would follow such intrusion; for, at the Colonial Sugar Refining Co., when the boilers were idle, they were filled with molasses which removed all the scale. When again required for work, the boilers were washed out with water. Another practice was to put eucalyptus logs into the boiler.

Mr. Bennie said that the sugar industry was one of those which was particularly suitable for the introduction of heat-power conservation by using the exhaust of power generators for heating purposes. He also suggested that if sufficiently concentrated, means might possibly be found for burning the molasses for steam raising.

Mr. Gamble said that molasses gave great trouble as a fuel owing to the formation of a gluey slag, that caused a great deal of trouble in the grates. It was almost impossible to use as a fuel.

Mr. Wm. H. Dobson said that the remaining colour in sugar was due to a small amount of molasses remaining on the surface of the crystals. In earlier days this was disguised by using Reckitt's blue, but to-day it was refined out.

The discussion was adjourned.
Mr. G. E. Gamble referred to a suggestion made by Mr. Bennie to use molasses as a crush fuel. He exhibited a specimen of slag produced by the combustion of molasses. It became very hard, and clogged everything with which it came into contact. He agreed that it would be quite feasible to design a special burner for the purpose.

ABSTRACT OF LECTURE

THE PRODUCTION OF COLD IN SMALL REFRIGERATORS.

By Roy J. Bennie.

The lecture outlined various methods used in the past for cooling materials—from the storage of ice by the ancients in caves and cellars, packed in straw, to later methods where the cold is produced as required. Apart from freezing mixtures, which are all expensive, the production of cold is attained by causing a gas to perform external work by expansion, thus causing it to draw upon its stored intrinsic energy with resultant fall in temperature. The gas may expand as it leaves a solution, or as it is formed by evaporation from its liquid state; but in every instance the cooling is produced by the conversion of its internal energy into external work. After outlining simple mechanical refrigerators, two non-mechanical domestic machines were described, showing how each obstacle had in turn been overcome.

I. Evaporation and Re-absorption of Ammonia.—Water dissolves thirteen hundred volumes of ammonia at 32 degrees F.; even at 68 degrees F. over seven hundred volumes are dissolved, while at 212 degrees F. very little is dissolved at all. But the solubility is roughly proportional to the pressure. So in the well-known "absorption-ammonia" refrigerator the ammonia is driven off from water in a boiler at a pressure of about 180 lbs. gauge, whence it is led through air- or water-cooled coils where it condenses to form liquid ammonia. The anhydrous liquid ammonia is allowed to trickle through a needle valve into a second series of coiled pipes placed in the cool chamber, where the pressure is about 15 lbs. gauge; some of the